Forest Pests and Diseases

Insects and diseases are constantly shaping California's forests. Bark beetles feed on tree inner bark and cambium, defoliators feed on needles and leaves, and pathogens attack every part of the tree. At low levels, insects and diseases perform necessary roles in forest ecosystems through pollination of non-conifer species, nutrient cycling, and thinning over-mature and unhealthy trees. When these forces act in conjunction with natural influences such as fire, drought, and wind, they can have a devastating effect on forests.

Insects and diseases are also introduced from outside California. These include such damaging pests as the eucalyptus borer and several diseases such as white pine blister rust. These insects and diseases may face few natural predators or resistance in California's ecosystems, can become established, and spread.

Elevated levels of insect or disease outbreaks can cause significant loss of forest resource values. They can cause economic losses by lowering the ability of sites to grow merchantable timber. Aesthetic values can also be reduced in recreation use areas. Large shifts in structure and composition can affect wildlife habitat and in particular those species that rely on dense canopy.

Management activities can also create forest conditions that favor the outbreak of forest pests. Altered natural fire regimes have resulted from successful fire control and past management practices. This, along with past high levels of mortality, has resulted in increased fuels accumulation. These increased fuels and dry conditions are allowing large, stand replacing fires in areas that historically have experienced small, low intensity fires. Other management activities that favor pest outbreaks include planting susceptible trees in areas of known disease, planting trees off-site, planting and/or promoting the growth of single species stands, leaving infested trees during harvest, and not harvesting infected trees quickly enough to reduce spreading. By modifying these practices, California's forests will be less susceptible to insects and diseases.

Findings on economic impacts from pests and disease

The economic impact pests have on forest resources is enormous. During peak outbreaks, such as those experienced during the early 1990s, estimates of statewide mortality were as high as five billion board feet (Rios, 2002). This is approximately seven times greater than the estimated historical yearly average lost to mortality of 700 million board feet (MMBF). The estimate on national forest lands alone varied from approximately 1,476 MMBF in 1995 to 736 MMBF in 2001 (Table 1) (U.S. Forest Service (USFS), 2002).

A portion of overall mortality is captured as salvage volume. The California State Board of Equalization's (BOE) salvage volumes range from 750 MMBF to one billion board feet of lumber recovered from mortality on all ownerships during the early 1990s (Figure 1).

Table 1. Volume loss due to mortality on national forest lands by year (million board feet)

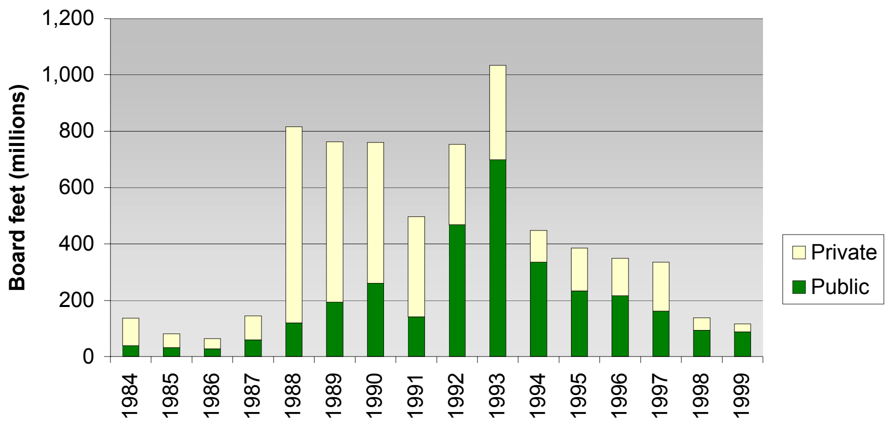
Year	Volume (MMBF)
1995	1,476
1996	772
1997	759
1998	633
1999	198
2000	540
2001	736

MMBF – million board feet

Note: includes prescribed fire and wildfire

Source: USFS, 2002

Figure 1. Volume* of salvage harvest by ownership, 1984-1999



**Includes salvage volume from fires and pest/disease*

Source: compiled by FRAP from BOE, 2002

Findings on major forest insects

Outbreaks of bark beetles recur without a predictable period in nature. They are usually preceded by severe weather conditions (e.g. drought) that make trees more susceptible to attacks. Bark beetles interrupt the flow of water and nutrients through the trees and often lead to death. Southern and northern California had widespread destruction of timber by bark beetles after the 1976-77 drought. Mortality declined after rainfall returned to average or above average levels.

The Sierra Nevada and Cascades, particularly the east side from Lake Tahoe to the Oregon border, experienced severe conifer mortality due to drought and bark beetles between 1991 and 1994 (USFS, 1996). Tree mortality was greatest in overstocked stands and in stands where past harvesting practices and successful fire control and suppression strategies encouraged the growth of tree species susceptible to insects, diseases, fire and drought. The extent of this outbreak dropped dramatically by 1998, with the exception of the Lake Tahoe Basin, which, while less than earlier years, still has high mortality levels (California Forest Pest Council (CFPC), 1999) (see sidebar on Lake Tahoe). However, only scattered mortality was reported in 1999 for the Lake Tahoe area (CFPC, 2000).

Drought conditions returned in 2000 and 2001, marking an increase in bark beetle related mortality (CFPC, 2002). All major bark beetles increased with the exception of the Jeffrey pine beetle. Regions most affected were the northern Sierras and northeastern and southern California. The primary bark beetles attacking trees are the fir engraver, pine engraver, Jeffrey pine beetle, mountain pine beetle, and western pine beetle.

The recent severe drought have left the forests of San Bernardino, Riverside and San Diego counties in Southern California significantly stressed and vulnerable to a bark beetle infestation that has created hundreds of thousands of dead and dying trees. The result has been elevated vegetation mortality – pines, white fir, cedar and chaparral – affects over 151,000 acres in the San Bernardino Mountains with tree mortality on 114,000 acres. Particularly infested is the Lake Arrowhead area of San Bernardino county (see photo). The magnitude and extent of mortality has produced fuels that pose major threats to life and property, ecosystem structure, function and long-term sustainability. Losses also include high value landscape trees and aesthetics (CFPC, 2002).

Mortality on other federal lands in southern California is less severe due to differences in climate, vegetation density and access and ownership patterns. About 8,000 acres are affected on the Cleveland National Forest and 2,000 acres are involved on the Angeles National Forest (CFPC, 2002).

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Defoliators are another forest pest that impact California's forests, reducing live foliage leading to growth loss and often mortality. A "defoliator" is an insect that feeds off the leaves and needles of trees such as the Douglas fir tussock moth and gypsy moth. In 1998, the Douglas fir tussock moth defoliated white fir on 44,000 acres of the Sequoia National Forest and the Sequoia-Kings Canyon National Parks (CFPC, 1999). Heavy defoliation also occurred on about 5,800 acres, restricted to areas within the national parks and the Hume Lake District of the National Forest (CFPC, 1999). In most areas, the outbreak began to decline in 1999.

A new infestation of the tussock moth appeared in 1999 in northeastern California, but evidence indicates that further defoliation will not occur in 2000 (CFPC, 2000). Populations of the lodgepole pine needleminer increased at some locations in Yosemite National Park in 1997 (CFPC, 1998). By 1999, the needleminer expanded its area in Yosemite. Populations continued to increase within Yosemite in 2000 and 2001 (CFPC, 2002).

Defoliator activity in hardwoods, particularly on oak species and elm trees, is very common throughout the natural and introduced ranges of the hosts. The highest defoliation of California black oak in southern California over the past ten years occurred in 1999 (CFPC, 2000). Defoliation was particularly heavy in the San Bernardino Mountains near Heaps Peak Arboretum. This area continued to show abundant defoliation, some mortality and more frequent twig and branch dieback of California black oaks in 2000 and 2001 (CFPC, 2002).

Damaging insects also impact urban forests. Several non-native pests are threatening eucalyptus trees, introduced from Australia (see sidebar on eucalyptus borer). Eucalyptus longhorned borers lay eggs under bark and exfoliating areas of the tree where their larvae bore through the outer bark. Other pests feed on eucalyptus leaves such as the eucalyptus snout beetle and chrysomelid beetle. The redgum lerp psyllid, a sap-feeding insect, has caused widespread defoliation. These pest populations are building, as their natural predators are absent from the United States.

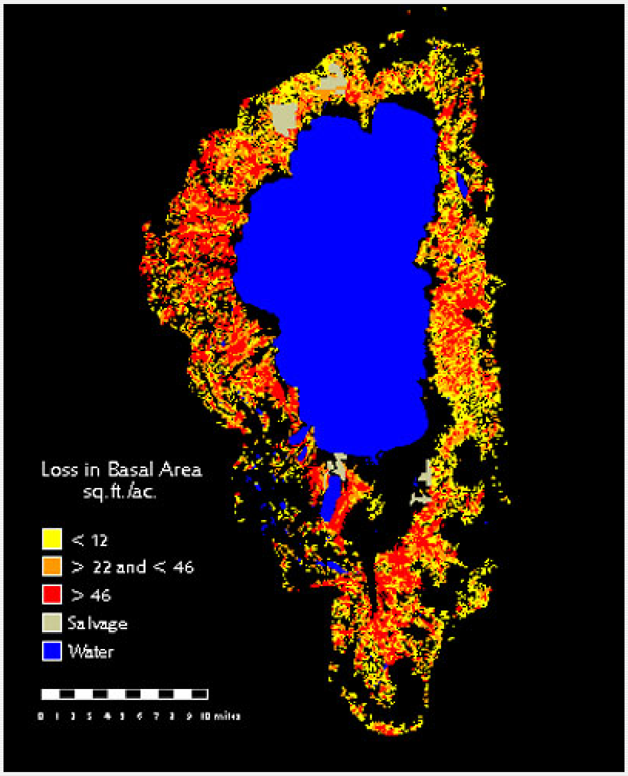
Lake Tahoe: Past harvesting activities, fire suppression policies and later regeneration in the Lake Tahoe Basin Management Unit (LTBMU) have contributed to an overly dense, fir-dominated forest that is vulnerable to the effects of drought. Nutrients in the soil and available moisture will support roughly one healthy tree for every three trees that currently exist.

The inevitable result of this "overstocking" is more disease, insect infestation, and mortality. Mortality in the LTBMU is of particular concern because it is in high-use recreation areas, as well as private properties. Such mortality causes unwanted reductions in vegetative cover and increases fuels.

Increasing white fir and Jeffrey pine mortality became evident in 1990 in the LTBMU. The interactions of water stress, beetles, and overstocking were the cause of this mortality (USFS, 1994). Mortality levels continued to rise through 1994 as the drought continued to weaken trees (CFPC, 1994) (Figure 3). Even as normal levels of precipitation returned, the overstocked areas in the LTBMU still exhibited high mortality levels. Growing concern prompted the California Board of Forestry to establish the Tahoe Area Zone of Infestation (ZOI) for bark beetles covering the LTBMU. Mortality has subsided and is currently isolated to a few patches. Because of the high recreation use and intermix of development, insect eradication is often difficult, contributing to the ongoing problem within the LTBMU.

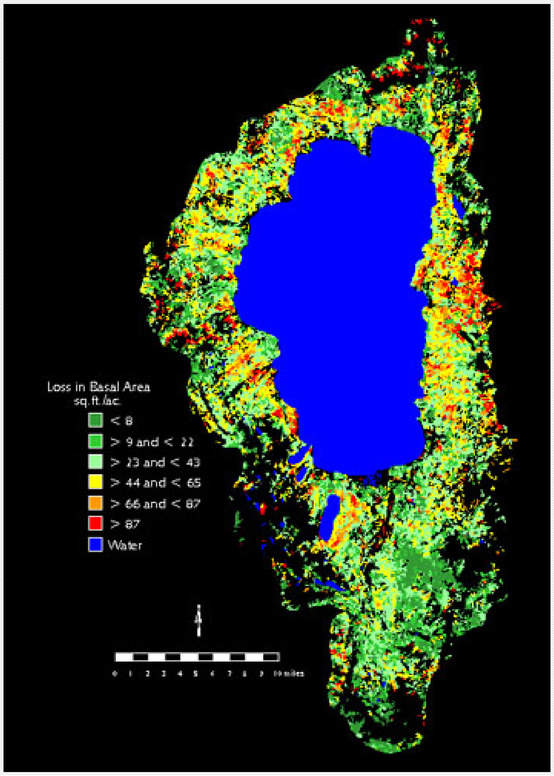
Figures 2 and 3 depict the extent of mortality on the LTBMU between 1988 and 1994 (Macomber and Woodcock, 1994).

Figure 2. Loss in basal area (ft^2 per acre) between 1988 and 1991



Source: Collins and Woodcock, 1995

Figure 3. Loss in basal area (ft^2 per acre) between 1992 and 1994



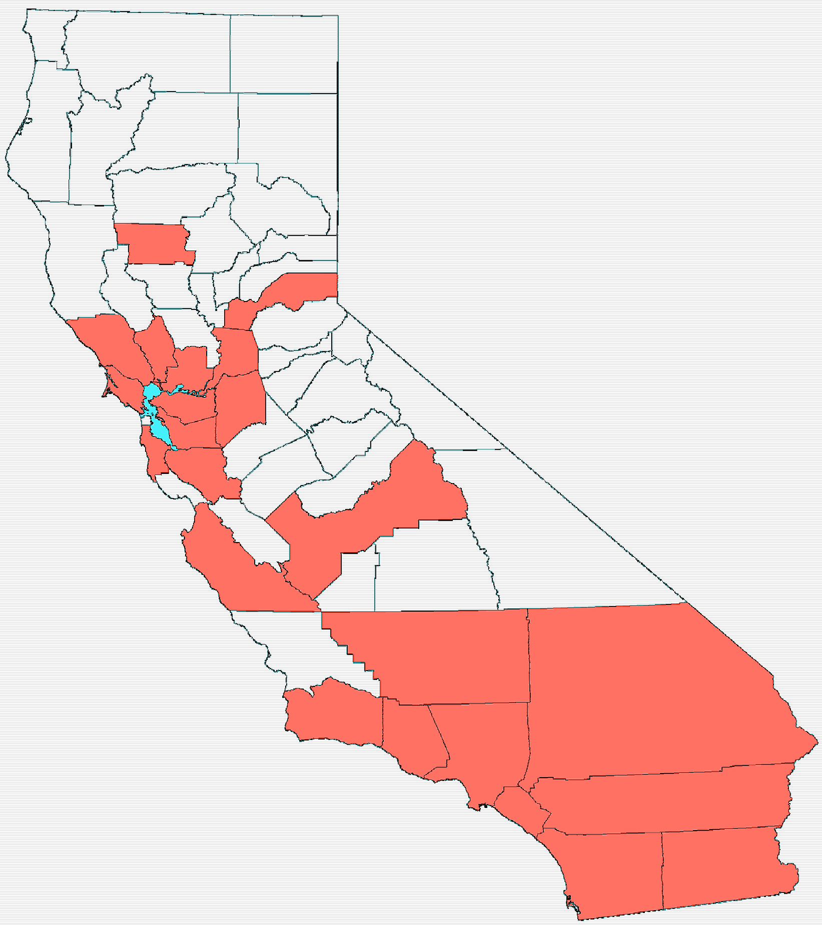
Source: Collins and Woodcock, 1995

Eucalyptus borers and other urban forest insects: Eucalyptus trees have become a significant component of many urban forest environments in California. Since their introduction from Australia over 130 years ago, eucalyptus trees have thrived in California and have been used for windbreaks, landscape trees, and fiber. These trees are appealing to use in urban forests because of their ability to grow with minimal supplemental irrigation, rapid growth, non-deciduous growth form, and relative freedom from damaging insects and diseases. Their continued use and the survival of certain species in the urban landscape are threatened. These once virtually pest free trees are now plagued by a growing number of serious new insect pests.

In 1984, the eucalyptus longhorned borer (Phoracantha semipunctata), a native of Australia, was identified as killing eucalyptus trees in southern California (Hagen, 1999). This beetle is now found throughout much of the State. Recently another Australian borer (Phoracantha recurva), has begun to cause damage. This beetle was detected in Ventura County in 1994 and was later detected in Los Angeles, San Bernardino, and Orange counties in 1995. Another leaf-feeding beetle was found in 1998, the Australian turtoise beetle, in Riverside, Los Angeles, Orange and San Bernardino counties.

Perhaps an even greater concern is the recent arrival of the redgum lerp psyllid (RGLP), a sap-feeding insect that has caused widespread defoliation throughout much of the Los Angeles Basin and other areas in the State (Hagen, 1999). At least five other psyllids native to Australia have been identified in the State. In California, population buildup and spread has been rapid because their natural predators are absent. However, recently California has introduced an RGLP parasite native from Australia to help control the pest. Similar efforts are underway to control other Eucalyptus pests.

Figure 4. Counties where eucalyptus borer is present



Source: USFS, 2002

The recent accidental importation of these new pests threatens to diminish California's urban and rural landscape. California's eucalyptus trees add tremendous value to the urban and natural landscape. They add beauty, enhance property values, provide shade, trap dust, and absorb air pollutants.

The financial and environmental impact of their loss could be large. Replacement would take decades with costs exceeding hundreds of millions of dollars. Increased energy consumption due to reduced shading of homes and buildings would impact some communities. Reduced air quality in urban areas would raise public health concerns. Widespread losses could potentially harm the Monarch butterfly, which uses eucalyptus trees from Santa Barbara to Monterey for shelter during winter months. For more information see eucalyptus borer.

Findings on major forest diseases

Sudden oak death

Sudden oak death, a new pathogen killing black oaks, coast live oaks and tanoaks, has been confirmed in twelve counties and its spread will likely continue.

Tens of thousands of tanoak, coast live oak, California black oak, Shreve oak, and madrone have been killed by a newly identified brown alga species, *Phytophthora ramorum*. This forest disease epidemic, known as sudden oak death (SOD), was first reported during 1995 in central coastal California (see sidebar on SOD). The pathogen also infects rhododendron species, huckleberry, bay laurel, California buckeye and big leag maple, but usually causes only leaf spot and twig dieback on these hosts. The host list is expected to expand as researchers continue their investigations of affected ecosystems.

As of July 2002, SOD has been confirmed in twelve counties (Alameda, Contra Costa, Humboldt, Marin, Mendocino, Monterey, Napa, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma) (California Oak Mortality Task Force, 2003). The disease is widespread in Marin and Santa Cruz counties in redwood forests with tanoak in the understory, and in mixed hardwood forests of oaks, bay, madrone, and other species. There are also nine isolated sites with confirmed SOD in Oregon. The Board of Forestry has declared a ZOI within these twelve counties, which allows the California Department of Forestry and Fire Protection to expend resources to address the SOD problem on State and private lands within the ZOI to help landowners remove trees that pose a fire or safety risk.

SOD may also be a threat to California's redwoods. Preliminary testing shows that redwoods appear to be susceptible to the same deadly disease that has infected oak woodlands along the central coast. The test results, if confirmed in laboratory experiments, could prove economically and environmentally ruinous for a state that is linked in the minds of people throughout the world with the giant trees. According to plant experts, DNA extracted from redwood sprouts on trees in Big Sur and on the University of California at Berkeley campus proved positive for *Phytophthora ramorum* spores.

The potential consequences of high levels of oak tree mortality from SOD are severe and far-reaching. Visually, the oak landscape characteristic of much of California could be altered dramatically. There could also be significant impacts to many wildlife species that are dependent on coastal oak forests for food and shelter including deer, turkeys, jays, quail, squirrels, and acorn woodpeckers. Ecological processes such as nutrient cycling, storage and release of water, and moderation of soil temperatures could also be affected (McCreary, 2001). An immediate concern is the increase of fire risk resulting from the addition of large quantities of highly combustible fuels. This risk is particularly serious because so much of the coastal forest is within urban interface areas where homes, businesses, and trees share the same area.

White pine blister rust (Cronartium ribicola)

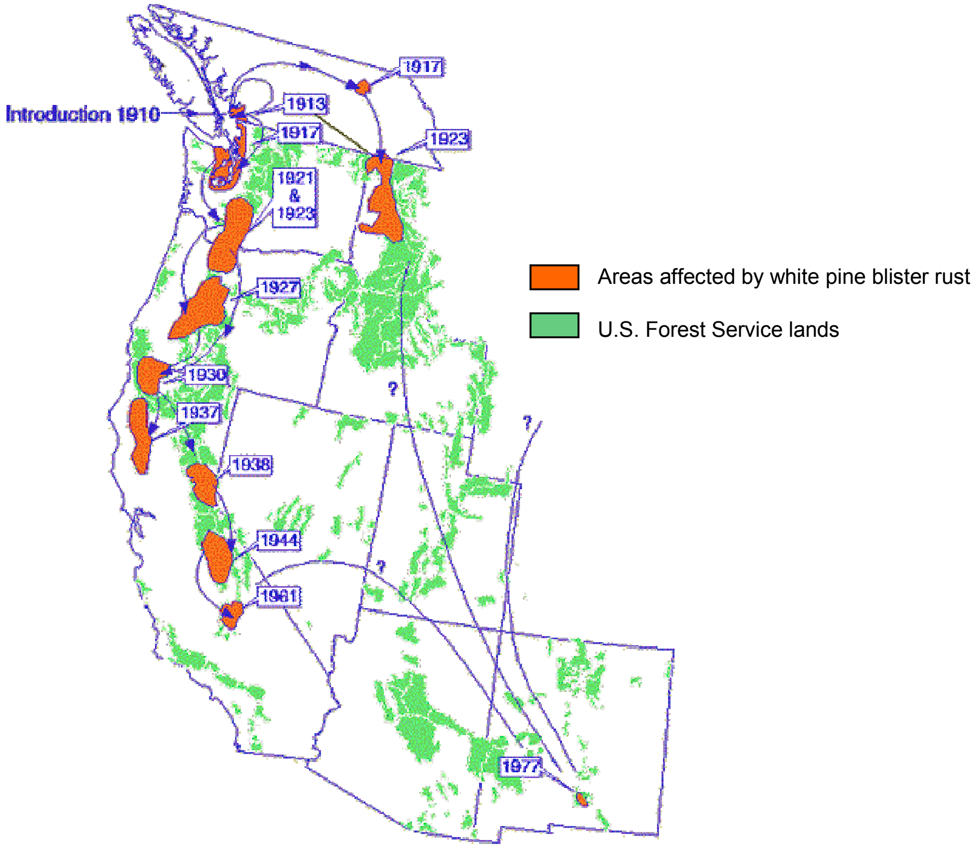
White pine blister rust, an introduced disease, has spread throughout the range of sugar pine in northern and central California (Siskiyou, Cascades, and Sierra Nevada ranges). Most mature trees survive infection, although in some locations the number of infections within a tree is great enough to make it more susceptible to bark beetle attack. This disease is likely affecting the size class distribution of sugar pine and limiting regeneration in areas with high susceptibility to infection, as smaller trees die more rapidly. In 1996, white pine blister rust was identified attacking "resistant" sugar pine saplings in two plantings at Mountain Home Demonstration State Forest, Tulare County (CFPC, 1997).

White pine blister rust has reached epidemic proportions and is predicted to have catastrophic ecological consequences.

White pine blister rust has reached epidemic proportions and is predicted to have catastrophic ecological consequences (USFS, 2001). Blister rust has caused more damage than any other conifer disease, resulting in losses of millions of dollars, reducing the genetic base of white pine species, and adversely affecting dependent wildlife. Attempts to control blister rust with chemicals or by eradicating alternate hosts have been abandoned as impractical and ineffective. However, a small percentage of sugar pine, western white pine, and southwestern white pine individuals display genetic resistance to attack by this disease.

In western North America, blister rust spread in serial jumps from a nursery near Vancouver, British Columbia, south through the Cascades and Sierra Nevada, and east to the northern Rocky Mountains (Figure 5). All native white pine species are susceptible. Economic impact has been most acute on the two large commercial species, western white pine and sugar pine, but ecological damage has been equally severe on high elevation species such as whitebark and limber pine in many places. Infection is not always uniform and often forms a mosaic pattern over the landscape where patches of intense infection give way to areas of lighter or no infection.

Figure 5. Spread of white pine blister rust across the northwest



Source: USFS, 2001

Pitch canker

One of the more significant diseases attacking forest resources, including urban forests, is pitch canker (see sidebar on pitch canker). This disease was first detected in Monterey pine in 1986. Since its introduction, pitch canker has spread to 18 counties from Mendocino to San Diego by 1997 (CFPC, 1998). In the three native Monterey pine stands, trees of all ages, including seedlings, are affected. The disease is killing seedlings and predisposing larger trees to bark beetle attack. By 1998, the disease was discovered for the first time in Solano County at a Christmas tree farm near Dixon (CFPC, 1999). This represents a significant jump for the disease since this location is hotter and drier than any other known site.

Pitch canker incidence has been steadily declining for about ten years.

As the spread of pitch canker in native Monterey pine stands continued in 1999, the California Native Plant Society considered a petition to the State Fish and Game Commission to list Monterey pine as a State threatened plant species. Current pitch canker activity in long-term monitoring plots in Santa Cruz County has dropped to near zero, although many trees show evidence of past damage (CFPC, 2001). Pitch canker incidence has been steadily declining for about 10 years and some previously heavily infected trees appear to be recovering in the absence of new infections. In the Soquel plot, where no live trees have been cut, 32 percent of Monterey pines were killed by pitch canker between 1987 and 2000

(CFPC, 2001). This is in sharp contrast to a 78 percent loss of the trees from the other two plots where trees were often removed before they died (CFPC, 2001).

Other diseases

Many diseases occur in California's forests. Dwarf mistletoe infection is very common and causes mortality of Douglas fir, pines, and true fir species. Approximately seven million acres were infested in 1994 with recreational areas heavily impacted by this disease (CFPC, 1994). The area that dwarf mistletoe affects does not change rapidly and with the next on set of drought, their relevance to forest health will increase (CFPC, 2002).

Root diseases, such as Armillaria, Heterobasidion annosus, and black stain root disease (Leptographium wageneri) occur in all major conifer species and many hardwood species. They are of concern because they originate from stumps and spread to other trees via root systems. They are most common in true firs, hemlocks and pines. Root diseases are widespread and commonly affect trees in logged areas and where management regimes favored the spread of the disease (e.g., planting susceptible species in stands of known infection). By 1998, approximately 4.2 million acres were infested (CFPC, 1999). Root diseases continued to be a problem in 2001, and are apparently becoming more widespread. New pockets of black stain root disease and Port Orford cedar root disease (Phytophthora lateralis) were found within the ranges of these diseases in 2001 (CFPC, 2002). Port Orford cedar root disease is spreading to the Klamath River Basin and in the Sacramento drainage within Shasta County.

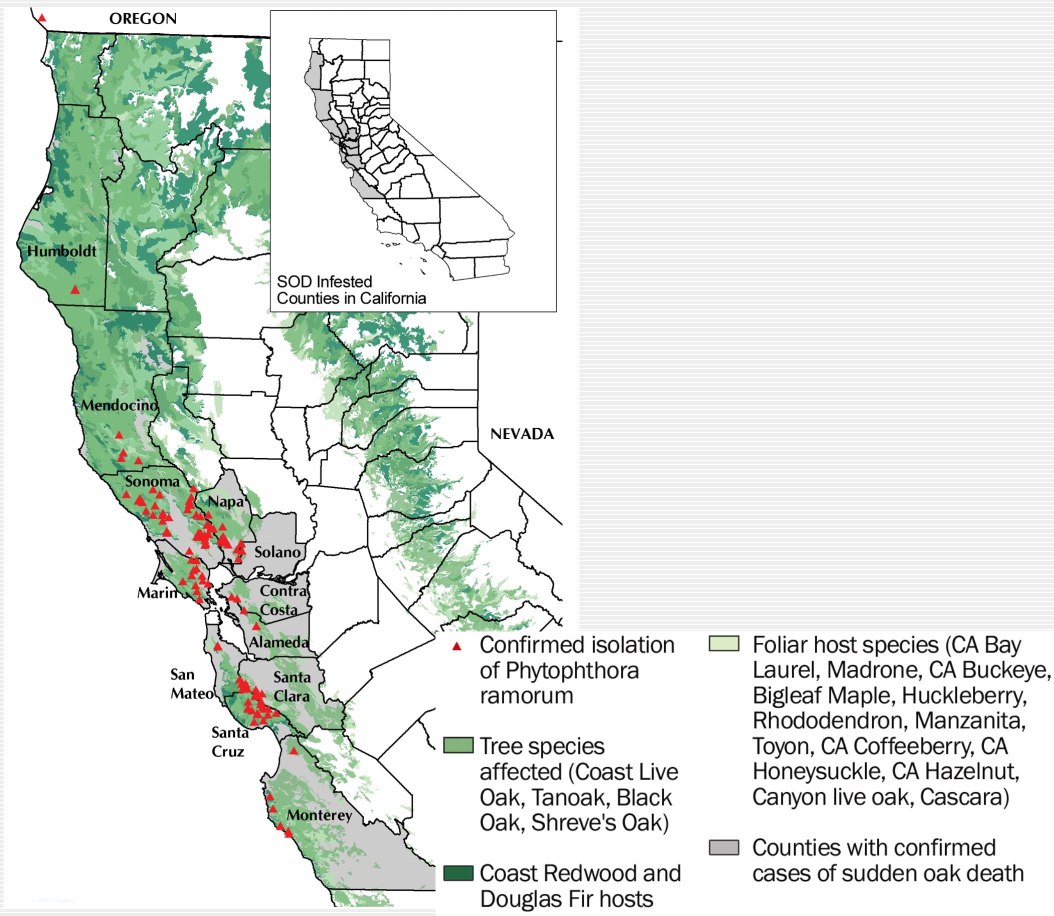
Other diseases affecting California's forest resources include Diplodia blight of pines and Elytroderma needle cast disease. Hardwood leaf and shoot blight included two species of fungi causing leaf spots on California black oak: a leaf spot and powdery mildew on blue oak and shoot and leaf blights on cottonwood and aspen.

Sudden oak death: Tens of thousands of tanoak *(Lithocarpus densiflorus*), coast live oak *(Quercus agrifolia*), California black oak *(Quercus kelloggii*), Shreve oak *(Quercus parvula* var. *shrevei*), and madrone *(Arbutus menziesii*) have been killed by a newly identified species, *Phytophthora ramorum*, which causes sudden oak death (SOD). SOD was first reported in 1995 in Marin County. The pathogen also infects rhododendron species, huckleberry *(Vaccinium ovatum*), bay laurel *(Umbellularia californica*), and California buckeye *(Aesculus californica*), but usually causes only leaf spot and twig dieback on these hosts. The host list is expected to increase as researchers at the University of California at Davis and University of California at Berkeley continue their investigations of affected ecosystems.

The known distribution of sudden oak death is expanding.

The known distribution of *P. ramorum* is expanding. As of July 2002, there are twelve counties with SOD; Alameda, Contra Costa, Humboldt, Marin, Mendocino, Monterey, Napa, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma (Figure 6). As of July 2002, the northernmost confirmed location of SOD is in Redway, Humboldt county. The southernmost confirmed location is Pfeiffer Big Sur State Park in Monterey County. The location farthest inland from the coast is in Solano County. The disease is widespread in Marin and Santa Cruz counties in redwood forests with tanoak in the understory, and in mixed hardwood forests of oaks, bay, madrone, and other species. There are also nine isolated sites with confirmed SOD in Oregon.

Figure 6. Distribution of sudden oak death*



**Updated February 2003*
Source: California Oak Mortality Task Force, 2003

This epidemic is characterized by a distinct set of symptoms. Symptoms include brown or black discolored bark on the lower trunk, exudation of reddish–brown to black viscous sap (seeping, or "bleeding") from the bark, the presence of fruiting bodies of the fungus *Hypoxylon thouarsianum*, and fine granular powder resulting from the tunneling activities of up to three species of bark and ambrosia beetles (Coleoptera: Scolytidae). These symptoms may not all be present on a tree. Foliage of affected trees may appear to die rapidly, turning from green to brown within a few weeks. However, trees in which foliage rapidly turns brown after an initial change in color from yellow–green or gray–green are likely to have had other symptoms for more than one year. The similarity of symptoms on affected tree species is suggestive of a common causal agent, although more research needs to be conducted to determine all of the interacting factors associated with tree death. Other pathogenic fungi isolated from coast live oaks and tanoaks may be associated with declining trees. Mortality is often associated with other causes such as Armillaria mellea, other Phytophthora species (especially for over-watered ornamental trees) or intentional herbicidal treatments in commercial timberlands.

The number of dead trees precludes sampling all mortality for the new pathogen. No reports of other symptomatic oak species have been confirmed. Valley oaks (Q. lobata) co-occur with infected coast live oaks in many locations, but symptomatic trees have not been observed.

A characteristic of SOD is the discontinuous and patchy distribution of infected trees. Infection centers or apparent expanding zones of infection are occasionally observed. However, the extensive geographic distribution and apparently rapid appearance of SOD along much of the Coast Ranges are suggestive of a unique pathogen in these forests.

The summer of 2000 saw the formation of the California Oak Mortality Task Force, an assemblage of public agencies, non-profit organizations, and private interests to address the issue of elevated levels of oak and tanoak mortality in California. The Task Force will implement a comprehensive and unified approach for research, management, education, and public policy. In April 2001, the Board of Forestry declared an official ZOI for seven counties affected with SOD. As SOD continues to spread, the ZOI continues to expand. The Board of Forestry has now declared the ZOI for the twelve counties known to be infested with SOD. Declaring a ZOI allows the California Department of Forestry and Fire Protection to expend resources to address the SOD problem on State and private lands within the ZOI and help landowners remove trees that pose an increased fire or safety risk.

In May 2001, the California Department of Food and Agriculture introduced emergency regulations aimed "to prevent further spread and harm to forests, parks, commercial and urban landscapes, and watersheds" by *Phytophthora ramorum.* The announcement of the new regulations came on the heels of similar quarantines aimed at reducing the risk of spread of *Phytophthora ramorum* from California to Canada (March 9, 2001) and Oregon (March 27, 2001).

The California quarantine regulates the movement of all known host materials within and out of the known infested counties. That means that any movement of any host material (except acorns and seeds) must be done under permit from the local Agricultural Commissioner's office. To date, all counties with known infestations are under quaretine. The host list includes tanoak, coast live oak, black oak, Shreve oak, California bay laurel, madrone, rhododendron species (except azaleas), evergreen huckleberry, and Viburnum. Regulations will be amended to reflect the recent isolation of the pathogen from buckeye, and from tanoak in Mendocino County. As research and monitoring continue, the list of counties and hosts are subject to change and it is best to check with local officials for the areas and species covered under the most recent regulations.

The California Department of Food and Agriculture is working with an interagency group to develop uniform enforcement guidelines that cover nurseries and wood and wood products dealers. Until those guidelines are in place, host plant materials that are not completely free of bark, including wood and wood products, are being regulated under the emergency regulations. Agricultural staffs are making visual inspections of nursery stock at production sites, as well as wholesalers and retailers, to determine if host plants are “free from” symptoms of SOD. Any host plants or plant parts showing symptoms are sampled and submitted for laboratory analysis to determine if *Phytophthora ramorum* is present.

The potential consequences of high levels of oak tree mortality from SOD are severe and far-reaching. Visually, the oak landscape characteristic of much of California could be altered dramatically. There could also be significant impacts to many wildlife species that are dependent on coastal oak forests for food and shelter including deer, turkeys, jays, quail, squirrels, and acorn woodpeckers. Ecological processes such as nutrient cycling, storage and release of water, and moderation of soil temperatures could also be affected (McCreary, 2001). An immediate concern is the increase of fire risk resulting from the addition of large quantities of highly combustible fuels. This risk is particularly serious because so much of the coastal forest is within urban interface areas where homes, businesses and trees share the same area. For more information see Sudden Oak Death.

Pitch canker: Pitch canker is a disease of conifers caused by the fungus *Fusarium subglutinans* f. sp. *pin*i. The fungus, which apparently was introduced into California, initially infects branch tips, causing needle wilt and tip death (Dallara et al., 1995). Resinous cankers result from infection of the trunk, limbs, cones, and roots. Death of the tree or its top may result from secondary attack by bark beetles. Bark, twig, and cone beetles are implicated as carriers of this pathogen.

Monterey pine *(Pinus radiat*a) and Bishop pine *(P. muricat*a) are the tree species most commonly infected in California. The fungus has been isolated from other conifers in California, and seedlings of additional tree species have been tested for susceptibility under greenhouse conditions. These include:

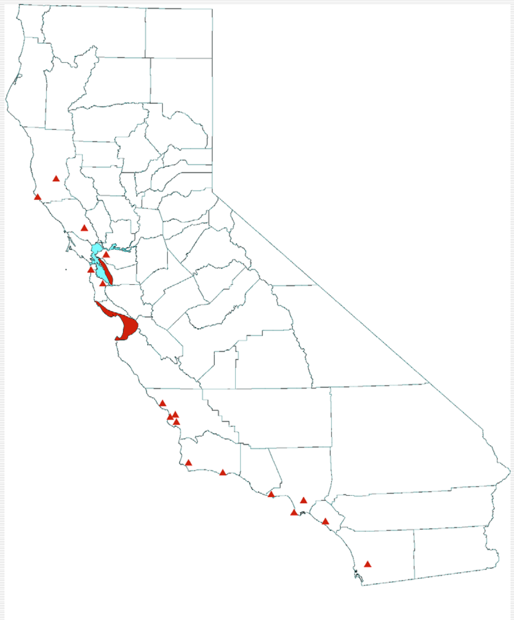
Table 2. Tree species naturally infected and susceptible to pitch canker

Naturally infected	Species susceptible in greenhouse seedling tests
Aleppo pine P. halepensis	Eldarica pine P. eldarica
Bishop pine P. muricata	Jeffrey pine P. jeffreyi
Canary Island pine P. canariensis	Mugo pine P. mugo
Coulter pine P. coulteri	Scots pine P. sylvestris
Gray pine P. sabiniana	Sugar pine P. lambertiana
Italian stone pine P. pinea	
Knobcone pine P. attenuata	
Monterey pine P. radiata	
Monterey knobcone pine P. radiata attenuata	
Ponderosa pine P. ponderosa	
Shore pine P. contorta	
Torrey pine P. torreyana	
Douglas–fir Pseudotsuga menziesii	

Natural infections of Monterey pine in California were not seen until 1986 when the pathogen was isolated from symptomatic tissue in Santa Cruz County. The disease occurs on Monterey pine and other conifers planted along road rights-of-way, and in landscape settings in the central coast of California, and has become severe in many locations. The pathogen also occurs in native stands of Monterey and Bishop pines.

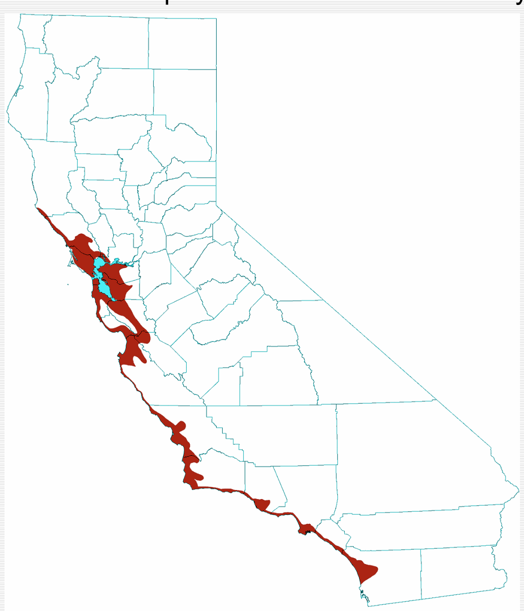
Pitch canker has spread to 18 counties from Mendocino to San Diego (Figure 7) and has the potential to spread to other areas (Figure 8). It has affected ornamental plantings of Monterey pine in Alameda, Santa Cruz, and northern Monterey and San Luis Obispo counties. Smaller numbers of infected trees have been found in Sonoma, Contra Costa, San Francisco, San Mateo, Santa Clara, Santa Barbara, and Los Angeles counties.

Figure 7. Areas of pitch canker infestation



Source: FRAP, 2001

Figure 8. Areas expected to lose more than 25 percent of their ornamental and native Monterey pine trees due to pitch canker over the next 10 years



Source: FRAP, 2001

Infected Christmas trees have been found in San Mateo, Los Angeles, Orange, San Diego and Solano counties. Pitch canker infections in the native populations of Monterey pine at Point Año Nuevo and the Monterey Peninsula were initially found in 1992. At both locations, the number of diseased trees has increased rapidly. The disease was reported in a native Monterey pine stand at Cambria in 1994 (CFPC, 1996). The two Mexican island native populations have not been assessed for pitch canker. A small number of infected trees have been found in native Bishop pine stands in southern Mendocino County.

Since pitch canker cannot be eradicated, regeneration of native stands and development of resistant trees is crucial.

Infected trees may exhibit a number of disease symptoms, but not all symptoms will necessarily be present on an individual tree. The first indication of infection on pines is usually the wilting and fading of needles on previously vigorous, unshaded branch tips, with resin exudation from the infection site. Foliage becomes yellow, then red, and falls from the branch. This produces dieback that is often striking, with loss of all needles between the branch tips and the most recent branch and cone whorls. Pinecones abort before or after reaching full size, and typically remain closed on infected whorls.

Removal of bark from infected areas, or cankers, reveals honey colored wood that is soaked with resin. Bole cankers are slightly sunken, up to approximately eight inches in diameter, and usually appear after branch dieback has occurred. Crystallized, white resin produced by bole cankers often coats lower limbs and several feet of bark below the infection. Infections of Douglas fir are characterized by tip dieback without copious resin exudation; callous tissue may form at infection sites.

In Monterey pine Christmas trees, resinous cankers are produced at the root crown; the entire tree subsequently wilts and dies. Christmas tree branch infections will occasionally occur in the absence of root crown cankers. Tree death does not follow as rapidly in these cases. Pitch canker symptoms may appear at any time of year, but initial symptoms in mature trees are most commonly observed in spring and summer. Symptoms have been observed in all age classes of trees. Bark beetle galleries are commonly associated with diseased plant tissues. Since the disease cannot be eradicated, regeneration of native stands and development of resistant trees is critical.

In June 1997, the California Board of Forestry established the Coastal Pitch Canker ZOI with the intent of slowing disease spread. This is the first time a ZOI was declared for a pathogen. The zone covers 23.1 million acres, including parts of 21 counties (17 infested counties and 4 adjacent counties that might reasonably be expected to become infested in the near future).

The Coastal Pitch Canker ZOI is still in effect, and the disease is still a management concern within the zone. Incidence of branch flagging appears to be less than in the several years following initial detection within California in 1986. Populations of several of the insect vectors could be at lower levels. Recent detection surveys have not found the disease north of Mendocino County, or in the central valley counties. Screening for genetically resistant native and ornamental Monterey pine continues.

For more information see pitch canker.

Findings on Aerial Survey Monitoring Program

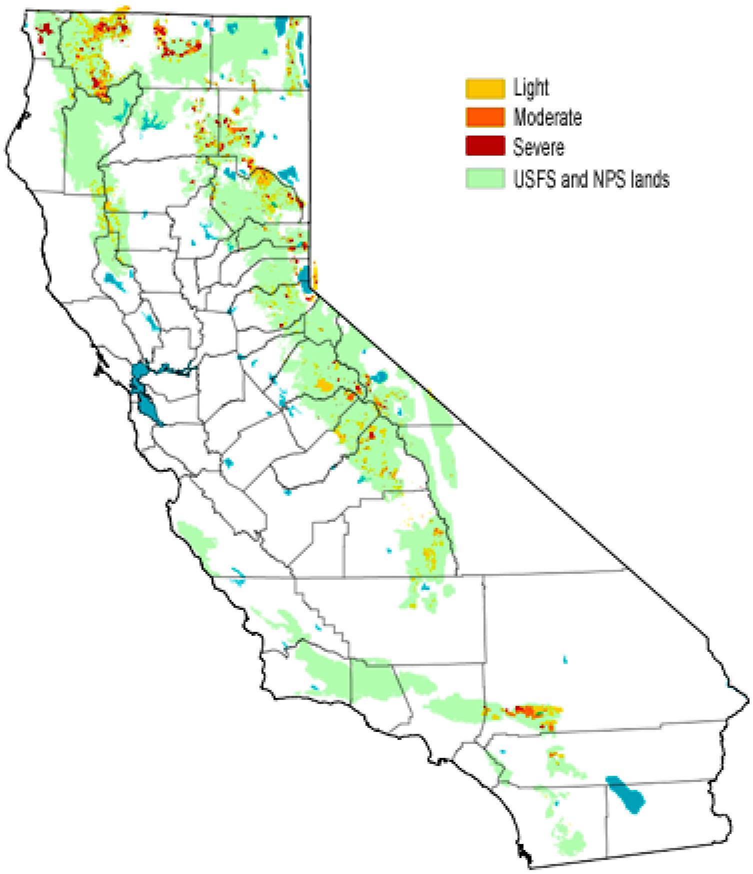
Aerial detection surveys are one method of efficiently collecting and reporting data on insect, disease, and other types of damage to forested ecosystems over large areas. The USFS Forest Health Protection (FHP) Program (see Forest Health Protection) and its state and federal cooperating partners have been conducting aerial surveys in California's national forests and national parks for the past eight years. These surveys provide information on insect and disease occurrence, conditions, and trends. The purpose of the aerial survey program is to detect and monitor current year conifer and hardwood mortality, defoliation, and other types of pest-caused damage by sketch mapping.

Mortality is defined as standing dead trees that have died since the last survey. Data collected from these aerial surveys are classified by the severity of mortality—areas with greater than 10 percent mortality (high), six to 10 percent mortality (moderate), and one to five percent mortality (low). Defoliation is also mapped into two levels, low defoliation (less than 50 percent) and high defoliation (greater than 50 percent). Other damage agents (e.g., snow and wind damage) are also documented and mapped during the survey.

Sketch maps created in-flight are captured digitally for input into a Geographic Information System (GIS). Volume and acres of mortality are calculated for individual forest types on forested productive acres (capable of growing 20 cubic feet/acre/year) within national forest lands. Volume statistics are calculated for national forest lands only. On national park lands, only acres of mortality and defoliation are calculated.

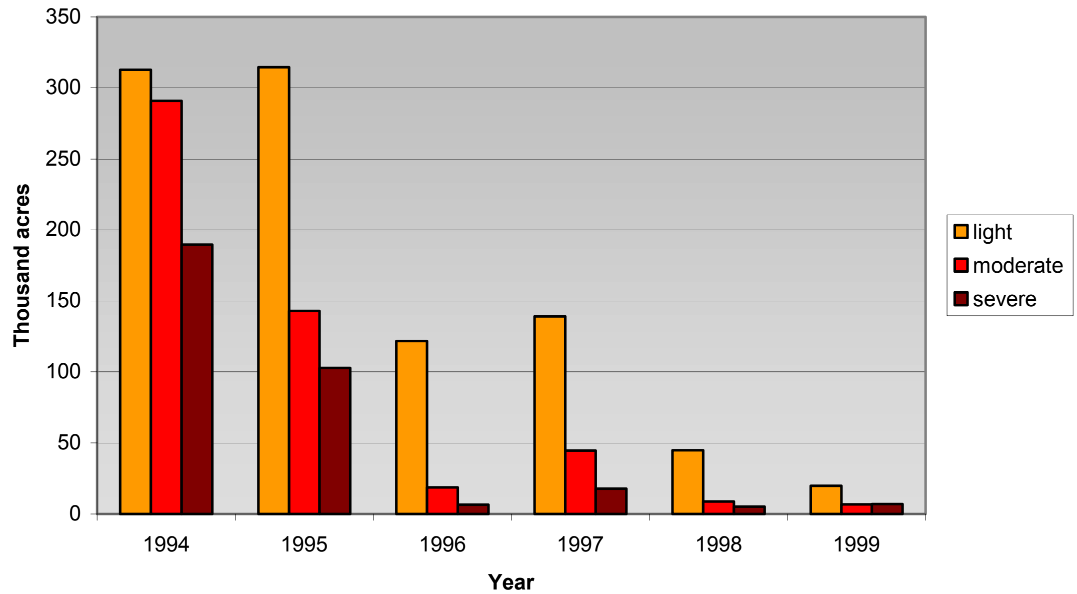
Results from the Forest Health Program aerial surveys show that mortality on surveyed national forest lands covered 809,000 acres in 1994 and 33,000 acres in 1999 (Figures 9 and 10). Peak levels seen in 1994 affected nearly five percent of the surveyed forest land base; and, by 1999, mortality had dropped below the long-term average of less than one percent. The high levels of conifer mortality observed in the early 1990s were the result of several years of inadequate rainfall, bark beetle attacks, overstocking, and, in some cases, altered species composition.

Figure 9. Location of mortality on federal forest lands (1994–1999)



Source: compiled by FRAP from USFS, 2002

Figure 10. Area of mortality on federal forest lands (1994–1999)



Source: compiled by FRAP from USFS, 2002

Findings on pest risk

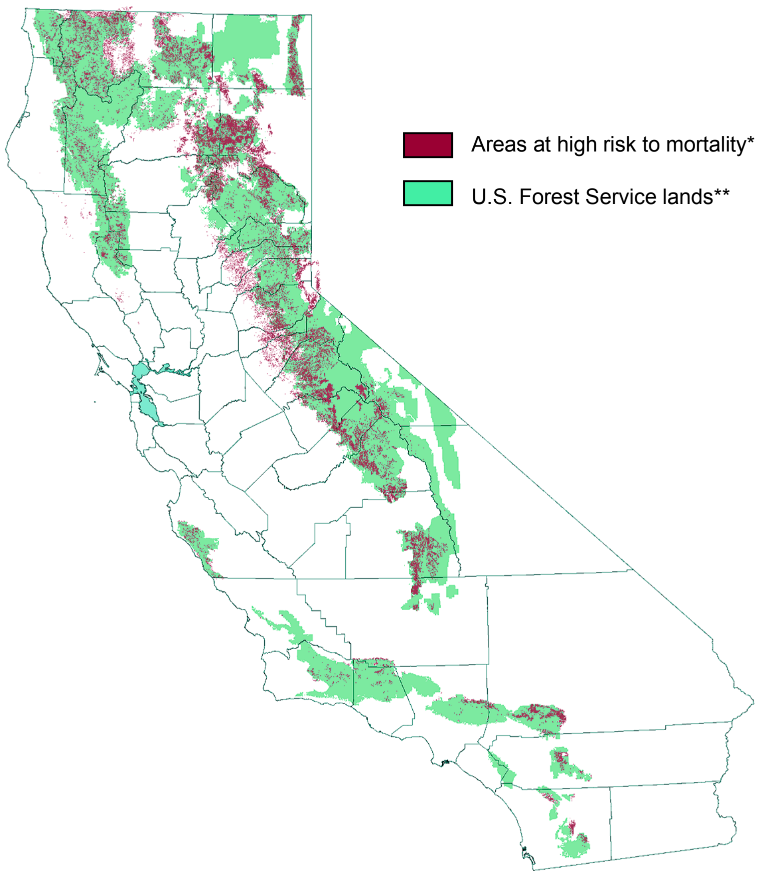
Much of California's forestlands are at risk to high levels of loss due to mortality. Given current management regimes and fire suppression tactics, stocking levels on many forestlands are very high. This increased stocking and buildup of fuels makes some areas very susceptible to insect and disease attacks. The USFS estimates that 3.5 million acres are at risk of up to 25 percent or more tree mortality over the next 15 years across the forested area of the State; a total of 2.3 million acres on national forest lands and 1.2 million acres on other lands. See Figure 11.

Pest risk mapping

Risk mapping is a national effort by the USFS to develop a GIS database containing information for evaluating forest health risk on all forested lands within the United States. The purpose of the risk mapping effort is to help determine where attention may be needed to address forest health issues. The forest insect and disease risk map is one of several layers of information needed to provide a national representation of forest health. The USFS initiated the forest health risk mapping effort in 1996 to help determine where additional attention may be needed.

In California, the FHP staff and specialists from several disciplines, including state cooperators, developed a statewide insect mortality risk map (Figure 11). This map depicts areas at risk of experiencing 25 percent or more tree mortality or growth loss from insects over the next 15 years. Implicit in this definition is a prediction that insect outbreaks and disease infestation will occur within the next 15 years, and will result in substantial levels of tree mortality. The 25 percent level is meant to represent an uncommon, rather extraordinarily high amount of mortality. Risk mapping is an iterative process that revises and fine-tunes the database as more and better information becomes available. Empirical data, models, and expert judgment are used to make projections of the risk of tree mortality or growth/volume loss from insects and diseases. Models developed for California are based upon rules and statistics developed for the national forests. These models are expanded to include state and private forest land. Rule structures are primarily based on stand density index, but also include precipitation, elevation, host type, and percent canopy cover of host species.

Figure 11. Areas at high risk to mortality* from insects through 2015



** greater than 25% tree mortality expected*

***includes national forest land, adjacent private land, Yosemite National park and Lassen National Park*

Source: compiled by FRAP from USFS, State, and Private Forestry, Forest Health Project, 2002; FRAP, 1999

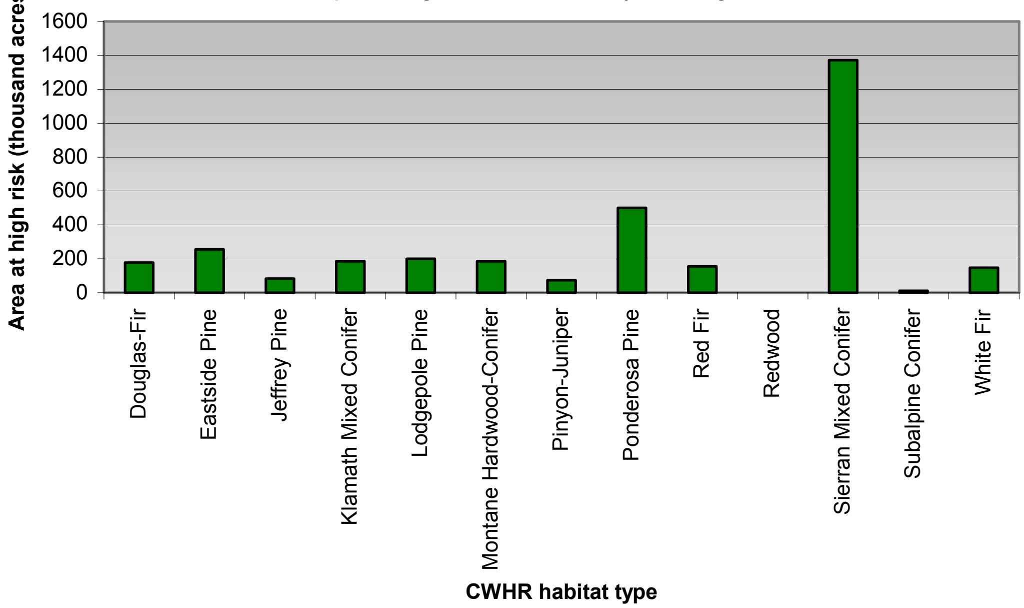
FHP staff is currently identifying the extent to which effective treatments are available to address the areas at risk. National emphasis can then be focused on those areas where effective treatments are available. Assisting land managers to reduce risk in the areas identified on the map, while keeping others areas healthy, is a national priority for the FHP Program. For more information see pest risk.

Pest risk by vegetation type and owner

The pest risk map was combined with the FRAP Multi-Source Land Cover Data to create a database with vegetation, ownership, county, bioregion, and working landscape classifications. The graphs below are examples of the type of data available for users to query (Custom Query).

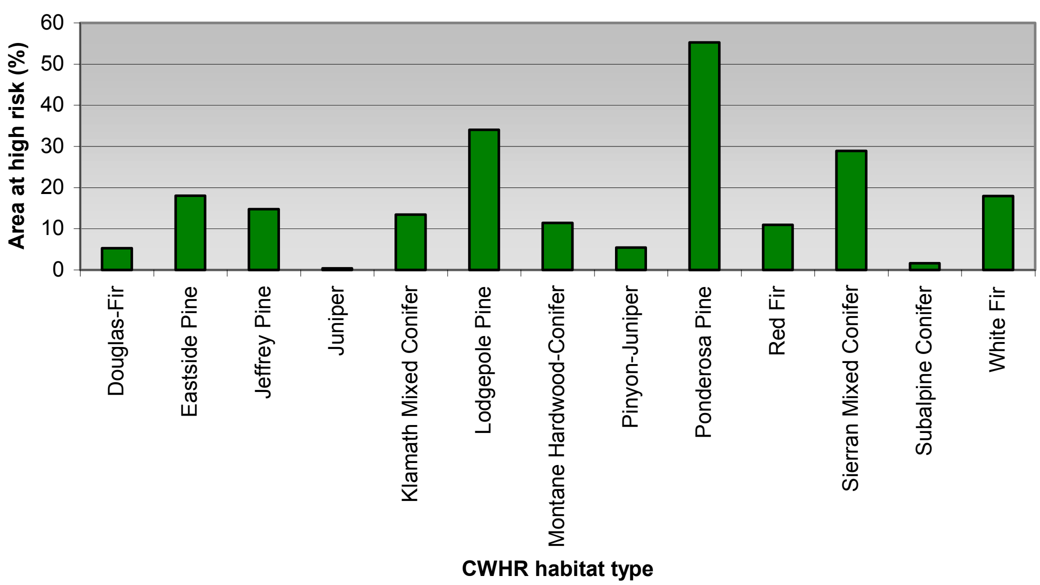
For example, Figure 12 shows that Sierran mixed conifer habitat having the greatest area of potential pest risk. However, as shown in Figure 13, ponderosa pine and lodgepole pine habitats have the greatest percentage of their area at risk. Nearly 60 percent of the ponderosa pine habitats in the State are at risk of having 25 percent or more mortality over the next 15 years.

Figure 12. Area of California Wildlife Habitat Relationship (CWHR) types on national forests and adjacent ownerships at high risk to mortality* through 2015



*greater than 25 percent tree mortality expected
Source: compiled by FRAP from USFS, State, and Private Forestry, Forest Health Project, 2002; FRAP 1999, FRAP 2002

Figure 13. Percentage area of California Wildlife Habitat Relationship (CWHR) types on national forests and adjacent ownerships at high risk to mortality* through 2015



*greater than 25 percent tree mortality expected
Source: compiled by FRAP from USFS, State, and Private Forestry, Forest Health Project, 2002; FRAP 1999, FRAP 2002

Glossary

BOE: California State Board of Equalization.

CFPC: California Forest Pest Council.

FHP: Forest Health Protection.

forest pests: Insects and related organisms and pathogens that damage trees and have the potential to be detrimental to ecosystem integrity or to achievement of resource management objectives. Many organisms, though detrimental to individual trees, do not necessarily have serious effects on the health of the forest.

Geographic Information System: A computer based system used to store and manipulate geographical (spatial) information.

GIS: See **Geographic Information System**.

infestation: The presence of a large number of pest organisms in an area, on the surface of a host or anything that might contact a host, or in the soil.

introduced forest pests: Non-native forest pests that have become established in North America.

LTBMU: Lake Tahoe Basin Management Unit.

MMBF: Million board feet.

natural enemies: Predators, parasites, or pathogens that are considered beneficial because they attack and kill organisms that we normally consider to be pests.

SOD: Sudden oak death.

USFS: U.S. Forest Service.

ZOI: Zone of Infestation.

Literature cited

California Forest Pest Council. 1994. Forest pest conditions in California–1994. Report prepared by the U.S. Forest Service and the California Department of Forestry and Fire Protection. Sacramento, CA: California Department of Forestry and Fire Protection.

California Forest Pest Council. 1996. Forest pest conditions in California–1995. Report prepared by the U.S. Forest Service and the California Department of Forestry and Fire Protection. Sacramento, CA: California Department of Forestry and Fire Protection.

California Forest Pest Council. 1997. Forest pest conditions in California–1996. Report prepared by the U.S. Forest Service and the California Department of Forestry and Fire Protection. Sacramento, CA: California Department of Forestry and Fire Protection.

California Forest Pest Council. 1998. Forest pest conditions in California–1997. Report prepared by the U.S. Forest Service and the California Department of Forestry and Fire Protection. Sacramento, CA: California Department of Forestry and Fire Protection.

California Forest Pest Council. 1999. Forest pest conditions in California–1998. Report prepared by the U.S. Forest Service and the California Department of Forestry and Fire Protection. Sacramento, CA: California Department of Forestry and Fire Protection.

California Forest Pest Council. 2000. Forest pest conditions in California–1999. Report prepared by the U.S. Forest Service and the California Department of Forestry and Fire Protection. Sacramento, CA: California Department of Forestry and Fire Protection.

California Forest Pest Council. 2001. Forest pest conditions in California–2000. Report prepared by the U.S. Forest Service and the California Department of Forestry and Fire Protection. Sacramento, CA: California Department of Forestry and Fire Protection.

California Forest Pest Council. 2002. Forest pest conditions in California–2001. Report prepared by the U.S. Forest Service and the California Department of Forestry and Fire Protection. Sacramento, CA: California Department of Forestry and Fire Protection.

California Oak Mortality Task Force. 2003. About Sudden Oak Death. Web site accessed September, 17, 2003. http://www.suddenoakdeath.org/

California State Board of Equalization. 2002. Annual harvest data files. Sacramento, CA. California State Board of Equalization.

Collins, J.B. and C.E. Woodcock. 1995. Assessment of drought-induced conifer mortality in the Lake Tahoe Basin using remotely sensed imagery. Technical Report Number 11. Boston, MA: Boston University, Center for Remote Sensing.

Dallara, P.L., A.J. Storer, T.R. Gordon, and D.L. Wood. 1995. Current status of pitch canker disease in California. Tree Notes 20:July 1995. Web site accessed July 21, 2003. http://frap.cdf.ca.gov/pitch_canker/prevention_management/treenotes.html.

Fire and Resource Assessment Program (FRAP). 1999. Teale Data Center Government Ownership, (GOVTOWNA, 1999). Sacramento, CA.

Fire and Resource Assessment Program (FRAP). 2001. Pitch Canker Task Force. Web site accessed July 21, 2003. http://frap.cdf.ca.gov/pitch_canker.

Fire and Resource Assessment Program (FRAP). 2002. Multi-source Land Cover, v02_1. Sacramento, CA. http://frap.cdf.ca.gov/projects/frapgisdata/select.asp.

Hagen, B. 1999. New pests threaten urban eucalyptus. Tree Notes 24:November 1999. Web site accessed July 21, 2003. http://www.ci.manhattan-beach.ca.us/pubworks/lerp/hagen.html.

Macomber, S. and C.E. Woodcock. 1994. Mapping and monitoring conifer mortality using remote sensing in the Lake Tahoe basin. Remote Sensing of Environment 50:155-266.

McCreary, D.D. 2001. Sudden oak death threatens coastal oak forests. Oaks 'n' Folks 17(1):1.

Rios, J. 2002. Personal communication (telephone conversation). February 25, 2002. Sacramento, CA: California Department of Forestry and Fire Protection.

U.S. Forest Service. 1994. California forest health past and present. San Francisco, CA: U.S. Forest Service, Pacific Southwest Region.

U.S. Forest Service. 1996. California forest health in 1994 and 1995. San Francisco, CA: U.S. Forest Service, Pacific Southwest Region.

U.S. Forest Service. 2001. Institute for Forest Genetics. Web site accessed July 21, 2003. http://www.fs.fed.us/psw/ifg/.

U.S. Forest Service. 2002. Forest Health Protection. Web site accessed July 21, 2003. http://www.fs.fed.us/foresthealth/id/id_guidelines.html.

U.S. Forest Service, State and Private Forestry, Forest Health Protection. 2002. Identifying areas at risk from forest insects and diseases. Web site accessed April 22, 2003. http://www.fs.fed.us/foresthealth/risk_maps/risk_maps.html